FRACTAL STATISTICAL STRUCTURE OF GLOBAL FOREST COVERS

Claudito R. Sabandal, Johnny Mark M. Bolante and Gemma M. Guigue
Northwestern Mindanao State College of Science and Technology
Labuyo, Tangub City

ABSTRACT

This study analyzes the fractal statistical structure of forest covers in countries across the globe with the end-in-view of determining the hidden factors that produced such a structure. Nature in its original state is fractal as evidenced by the predominance of smaller observations than larger observations. The study made use of the descriptive research design to determine the current state of forest covers all over the world. Data were obtained from the Global Forest Cover file of the World Bank. Countries with low forest covers are characterized by population pressures coupled with ineffective implementation of forest laws and regulations making such countries vulnerable to fast rates of deforestation. Moreover, these countries have natural topographies that are not suitable for natural forest growths or where population pressure exerts a great deal of influence on the rate of deforestation. Countries with high forest covers have low population and have in place some of the better-implemented forest regulations and laws.

Keywords: fractal, forest covers, statistical structure

Introduction

The universally-accepted definition of a forest area is a land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens (World Bank, 2012). It has been noted that in the northern hemisphere, the extent of forest cover is increasing primarily due to plantations or regenerated forests. Nonetheless, the original or ‘old growth forest’, which is considered more diverse and performs more ecological functions, is declining because of continued logging (Global Forest Resources Assessment, FAO, 2005). The nation’s remaining forest cover is often taken as a measure of the extent to which the State protects its environment and natural resources.

There are different points of view as regards the role of logging. Some argue that logging is a method of deforestation; others maintain that it does not lead to stable loss of forest vegetation and does not, therefore, establish deforestation. Whatever be the argument, the fact remains that the original forest growth can never be replaced by plantations nor regenerated forests. There are other factors that lead to deforestation. First, human activity upsets forest cover unswervingly through activities such as reaping for timber and clearance for cultivation. Second, social and economic services also have significant unexpected impacts by encouraging strategies and ways of action that can start chains of events leading to deforestation. From original times, humans have clean land for settlements and agriculture. Alteration of forests to agricultural property takes place as individuals and clans open areas to feed themselves and their families. It also takes place in a large measure with packages planned and executed by governments and agricultural productions to relocate populations and to upsurge agricultural production, frequently of cash crops for trade. In emerging countries, and particularly in tropical forests, land is cleaned under traditional agricultural systems known as *Kaingin* ('slash and burn' systems because of their dependence on clearing and burning a covering of forest to make land suitable for cultivation) and likewise by travelers moving from other rural regions where the land is rare. Some kind of adaptation of forest land is for structure improvements such as road building, dam construction, mining operations and other structure development actions. Construction of roads disturbs the extent of forest cover to build roads. The building of roads provides a direction for population movement and more sanction for maintenance, agriculture and the development of urban axes. The part of forest cleared right by road-construction may not be very huge, but clearance and disintegration of forestland following road-building are important. Road-building in forested zones leads to the destruction of the forest which eventually leads to widespread clearance of forest. Third, population pressure is often referred to as a main reason of deforestation - and many people consider it to be a major cause of deforestation. The proposition, however, is not directly supported by empirical observations since cases of growths in population rising at similar periods as deforestation, no alteration in the region of forest, and even intensifications in the forest area. The effect of increased population densities seems to depend on economic chances available to rural society, agricultural and cropping systems, and contact to markets for timber and non-timber crops, as well as for other methods of production. Wood and charcoal are still the main source of energy for most people in undeveloped countries. Cutting of trees for fuel evidently has impacts on forests, principally near urban areas, but most experts now consider that this is not a major reason of deforestation. Increased deforestation and population growth happen at almost the same time. Fourth, the global climate differs with alterations in the polar ice caps, in surface and subsurface temperatures of the oceans, by absorption, reflection and conduction of energy in the form of light and heat from the surface of the earth. Meanwhile, nearly two-thirds of the earth external is covered by oceans and the polar ice caps, these, rather than forests and other land topographies, are the most important physical features of the globe's disturbing climate. Generally, it was thought that the occurrence of forests attracted rain and that forests play a role in controlling or regulating rainfall (Global Forest Resources Assessment, FAO, 2005).

Deforestation is one of the most serious problems encountered globally. There are many consequences faced when the disintegration of the forest arises. There are many benefits of forests. Forest covers provide shelter and protection of animals and prevent soil erosion and other environmental disintegration. It also provides protective facilities to the environment, especially in mountainous regions where steep slopes and geological activity that causes uncertainty. Forest also absorbed more carbon and increases the reservoir of ground waters. The forest offers an inclusive range of economic and social to civilization. This study analyzes the fractal statistical structure of forest covers in countries across the globe with the end-in-view of determining the hidden factors that produced such a structure.

Conceptual Framework

The study is anchored on the theoretical framework provided by fractal statistics, namely, that the measurements in nature are fractals. Nature in its original state is fractal as evidenced by the preponderance of smaller observations than larger observations (Padua, 2014). When the distribution of the observations deviates from a fractal structure, then some intervention into the natural processes may have taken place to explain the variation from the original state. The natural state or fractal state may, however, not be the ideal or desired state. In fact, it is precisely these interventions that produce desirable outcomes that are sought or hunted. A random variable X is said to obey a fractal or power law distribution if it obeys the probability distribution:

$$f(x) = \frac{\lambda-1}{\theta}\left(\frac{x}{\theta}\right)^{-\lambda} \quad , x > \theta > 0, \lambda > 1$$

The quantity λ is called the fractal dimension of X because of its similarity with the definition of the box-counting dimension of Benoit Mandelbrot (1982), namely

$$\lambda = \frac{log(f(x))}{\log(\frac{\theta}{x})}$$

Padua (2013) stated and proved the fundamental theorem of fractal statistics which provides a way for determining whether a set of observations has a fractal distribution or not. The fundamental theorem states that "X has a fractal distribution if and only if $y = \log(\frac{x}{\theta})$ has an exponential distribution with rate parameter β = λ-1."

In practice, the fractal dimension of a set of observations is determined to see how much smaller observations there are than larger ones. Thus, a fractal dimension of 1.70 implies that 70% of the observations are considered small than large. Moreover, the higher the fractal dimension the more rugged becomes the observations. The fractal dimension also has another use, namely, that one can "embed" the observations in a space of higher fractal dimension. The embedding process can be thought of as a process of finding the underlying reasons for the fractal or non-fractal behavior of the observations.

Actual observations, such as global forest covers, may display non-fractal behavior. Fractal statistical analysis, then, proceeds to find the "hidden fractal dimension" by removing some observations that cause the non-fractality. The deleted observations are then analyzed to determine what common characteristics they possess to cause the data to behave in a non-fractal way. This conceptual paradigm is illustrated in

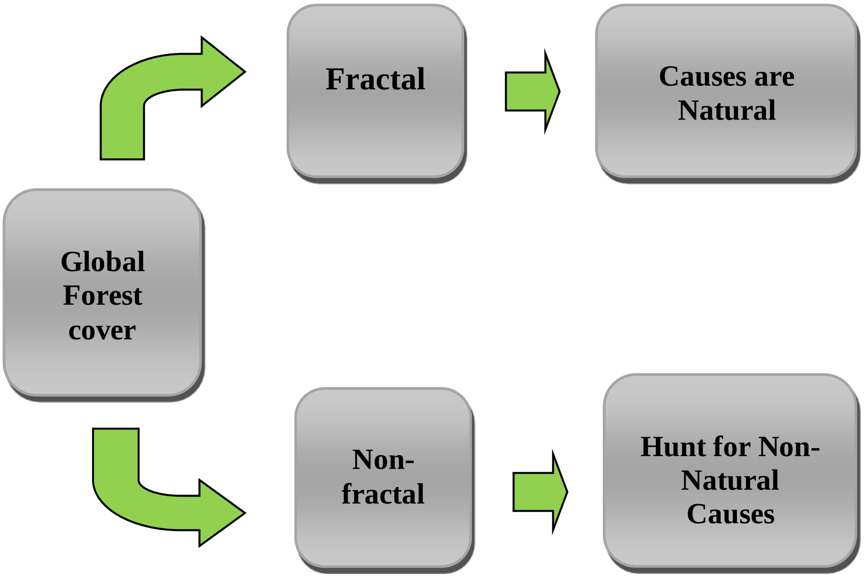

Figure 1: Conceptual Framework for the Study

Research Design and Methods

The study made use of the descriptive research design since its main purpose is to determine the current state of forest covers all over the world. Data were obtained from the Global Forest Cover file of the World Bank (World Bank, 2012). World Bank defines “forest cover” as a land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.

The data set was first cleaned by deleting an observation with incomplete information. A total of 194 data points was used and transferred to EXCEL for processing. Using statistical software *(Minitab)*, the histogram of the observation was determined. If the histogram behaved as a fractal distribution, then the countries in the (λ-1) x 100% smallest observations were analyzed. The histogram below shows a typical histogram of fractal observations:

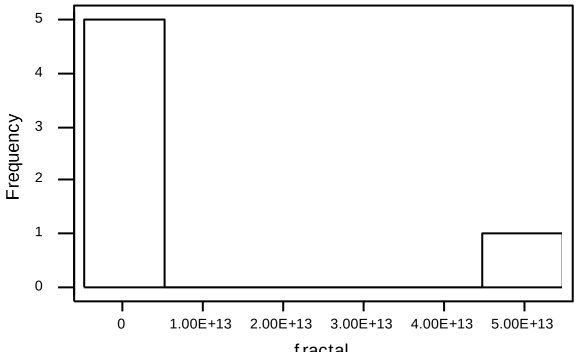

Figure 2: Histogram of a typical fractal data set

However, if the histogram were not fractal, then some observations were segregated from the analysis. In many cases, the histogram would suggest an exponential distribution so that Y=exp$\left(\frac{x}{\theta}\right)$ would be fractal. The histogram below shows a typical exponential distribution for the transformation log(x/min):

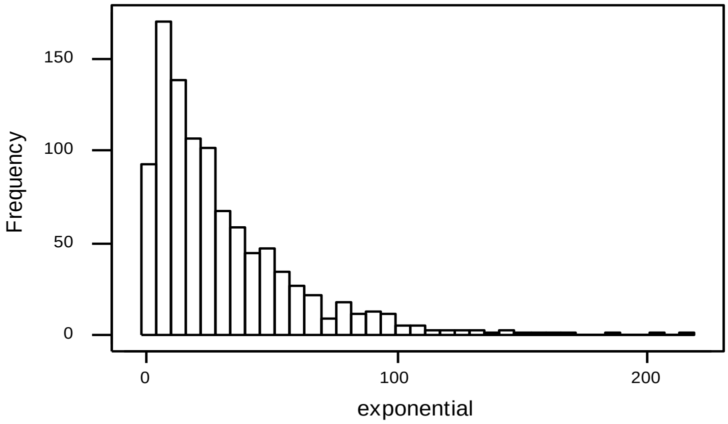

Figure 3: Histogram of a typical exponential distribution

If the histogram reflects a behavior similar to Fig. 3, then using the fundamental theorem of fractal statistics, the transformation Y = EXP (x/min) will transform the data to a fractal data set. If the histogram reflects a fractal distribution like Fig. 2, then the transformation Y = log (x/min) will convert the histogram of the data into an exponential distribution as Fig. 3.

Results and Discussion

In 205 observations, four countries, namely, Greenland, Oman, Qatar and San Marino have natural topographies. These countries account for the zero forest covers noted i.e. either the country is covered with ice or is mainly a barren desert. Fig. 4 shows the histogram of the forest cover observations:

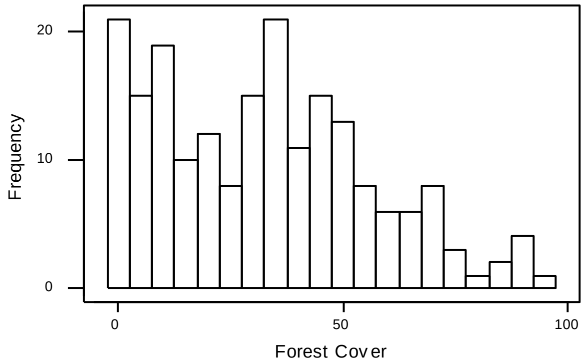

Figure 4: Histogram of the Forest Cover of Various Countries

The histogram suggests an exponential distribution around 27% onwards. We deleted the observations with forest covers up to 26% to produce the following histogram:

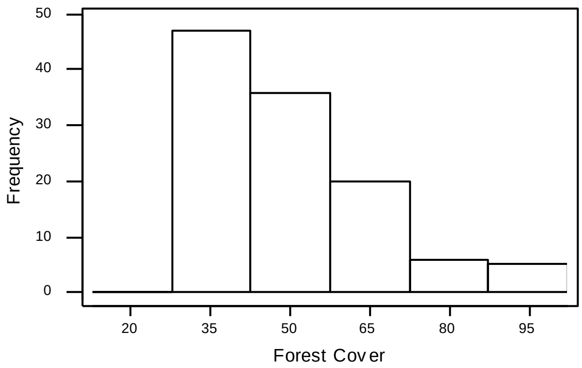

Figure 5: Histogram of the Forest Cover Data with Deleted Observations

Figure 5 shows that the forest cover data with 89 observations deleted are almost distributed as exponential suggesting that the original forest cover data must be exponentially distributed. It follows from the fundamental theorem that the transformation Y = min*exp(data) must be fractal. This is confirmed by the histogram below which shows a fractal-like behavior:

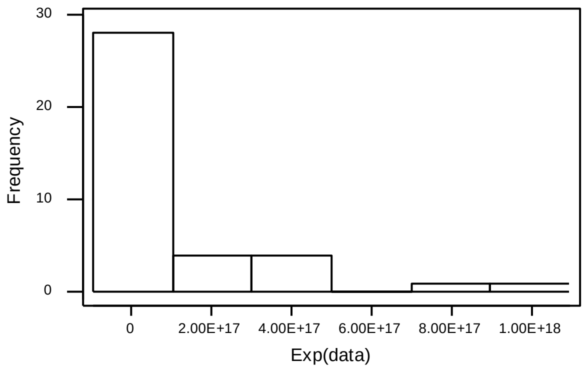

Figure 6: Histogram of the transformed data with the 89 smallest observations removed

Figure 6 shows a fractal-like histogram except for the presence of spikes on the right-hand side of the histogram. The mean forest cover of the remaining 116 observations was found to be 49.24%. Since the forest cover data suggest an exponential distribution with rate parameter $\beta = 1/49.24 = .0203$, we proceeded to test the hypothesis of exponentiality of the original data set by the Ryan-Joiner test. The Q-Q plot of the theoretical exponential with mean 49.24 and the observed forest covers data is shown below:

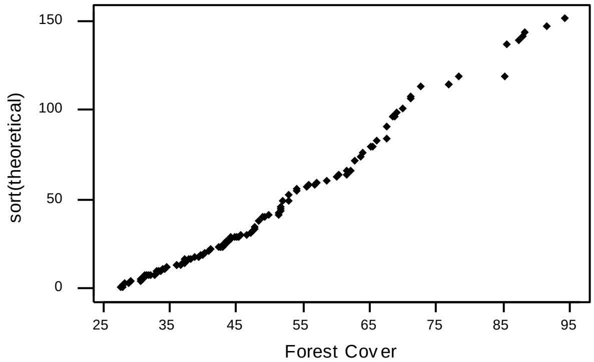

Figure 7: Q-Q Plot of Theoretical Exponential with Forest Cover Data

Figure 7 shows as a light departure from linearity at the right tail end of the plot. Regression analysis produced the following results:

Table 1: Ryan Joiner Test Results

The regression equation is
sort(theoretical) = - 73.4 + 2.36 Forest Cover

Predictor	Coef	SE Coef	T	P
Constant	-73.367	1.549	-47.37	0.000
Forest C	2.36427	0.02982	79.29	0.000

S = 5.266   R-Sq = 98.2%   R-Sq(adj) = 98.2%

Regression analysis showed a highly significant slope of 2.36427 beyond the .01 probability level. The slope should be divided by 2 to account for the fact that the percentage of forest cover data spans 0 to 100% only whereas the theoretical exponential random variables generated do not have this constraint. That is, the real slope is 1.18 (close to 1).

Discussion

The countries which were deleted consist with minimal forest covers like Greenland, Oman, Qatar, San Marino, Egypt, Faeroe Islands, Libya, and others in the Arab States. The topographies of these countries, mainly desert lands or ice-covered States, explain the very low forest cover measurements for them. On the other hand, the countries with large to very large forest covers like Suriname does not face the population and migration pressures that have led to deforestation in other countries; FAO (2005) estimated the rate of deforestation in1990–2000 to be virtually zero. More than 400,000 hectares of swamp and savanna forests are degraded due to poor-quality logging and mining operations. An occasional forest fire is considered to be the main present threat to forest resources (FAO 2005. State of the World's Forests 2005 FAO, Rome, Italy).

Micronesia, also part of the list of countries with highest forest covers has implemented successfully a forest stewardship program. In Pohnpei and Kosrae have successfully passed conservation laws which designate certain mangrove areas and upland forest areas reserve sites to protect the exotic plants and animal habitats. Monitoring of forest conditions and public education and negotiation on forest conservation and management has continued and expanded in all states; mangrove forest management plans are being developed and implemented successfully in Pohnpei and Kosrae. Increased efforts in educating the public on the forest conservation using the tapes produced by the USDA-FS research staff. Forestry and agroforestry nurseries have been expanded in all states, with the help of USDA-FS training and assistance. Forestry and agroforestry extension to private landowners is delivered through extension visits, workshops and the production of planting materials. The number of seedlings distributed to farmers of fruit trees has increased as well as for shade and beautification tree seedlings (Leigh Beck State & Private Forestry, USDA Forest Service).

Almost all countries with high forest covers were found to have smaller populations as well so that population pressure does not appear to be a problem in these States.

In contrast, the Philippines with only 26.1% remaining forest cover as well as India with only 23.1% face the stark realities of huge and increasing population. In fact, these countries also figure prominently among States with fastest depleting forest covers. Population pressures coupled with an ineffective implementation of forest laws and regulations make such countries vulnerable to fast the rates of deforestation. It may be mentioned that tropical countries are the natural habitat of many species of trees, yet, because of rapid population growth, these are the very same countries that deplete their forest resources fastest.

Conclusion

The distribution of forest covers of countries all over the world obeys an exponential distribution. The corresponding fractal observations, obtained by taking the exponential of the forest covers, had a fractal dimension of 1.023 indicating that around 2.3% of the world's forest covers are small. These countries are characterized as countries whose natural topographies (desert or ice-covered) are not suitable for natural forest growths or where population pressure exerts a great deal of influence on the rate of deforestation. Countries with high forest covers such as Micronesia and Suriname have low population and have in place some of the better-implemented forest regulations and laws.

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